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[54] **FUEL SYSTEM**
9 Claims, 4 Drawing Figs.

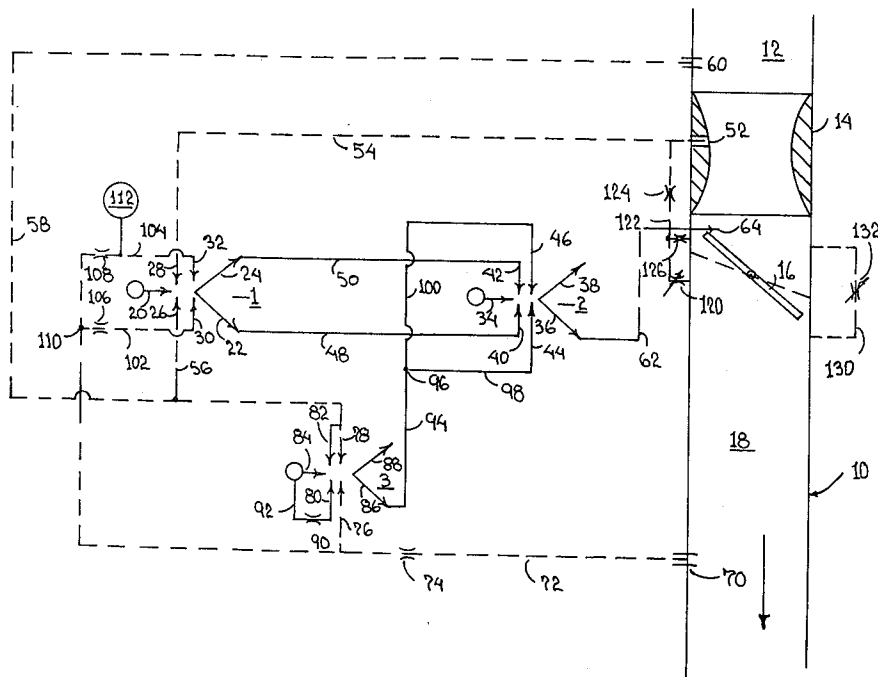
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 [51] Int. Cl. **F02m 7/06**
 [50] Field of Search 261/36.1,
 39.2; 137/81.5; 123/119

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ABSTRACT: A fuel control system utilizing proportional fluidic amplifiers wherein the primary control is responsive to mass airflow derived from a venturi in the engine intake manifold. The invention is particularly characterized by the addition of compatible fluidic enrichment devices superimposed on the primary control. One enrichment device utilizes a saturable fluidic amplifier sensing manifold vacuum as a control parameter to provide selective enrichment under full power conditions. Another enrichment device develops a derivative signal proportional to the rate of change of manifold vacuum to provide a temporary fuel augment during acceleration. Idle bleed means are provided to modify the mass airflow to fuel relationship during idle conditions.



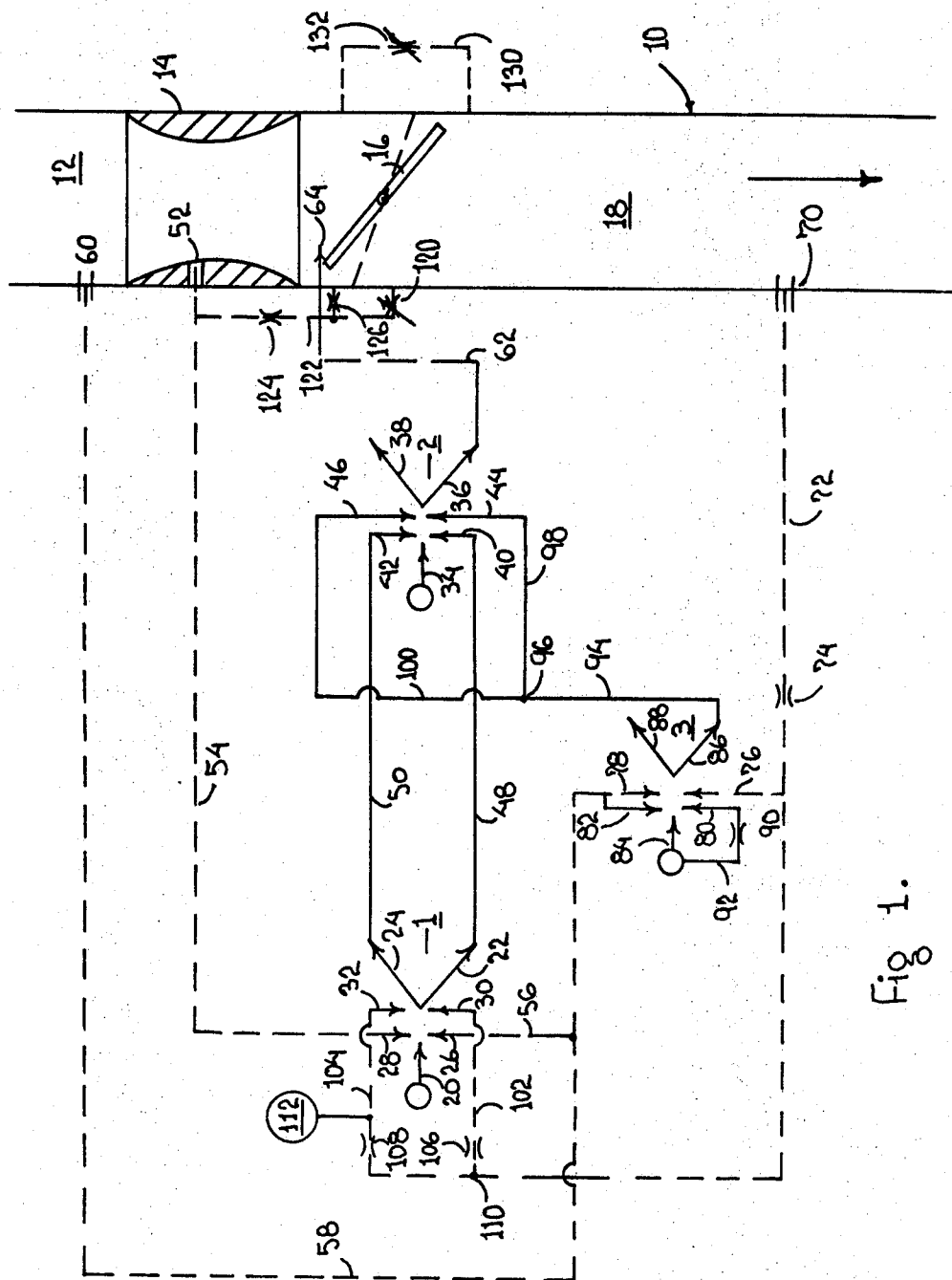


Fig. 1.

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Fig 2.

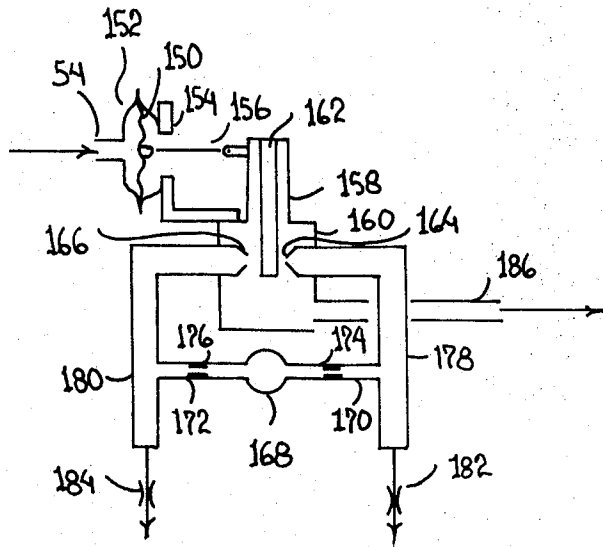
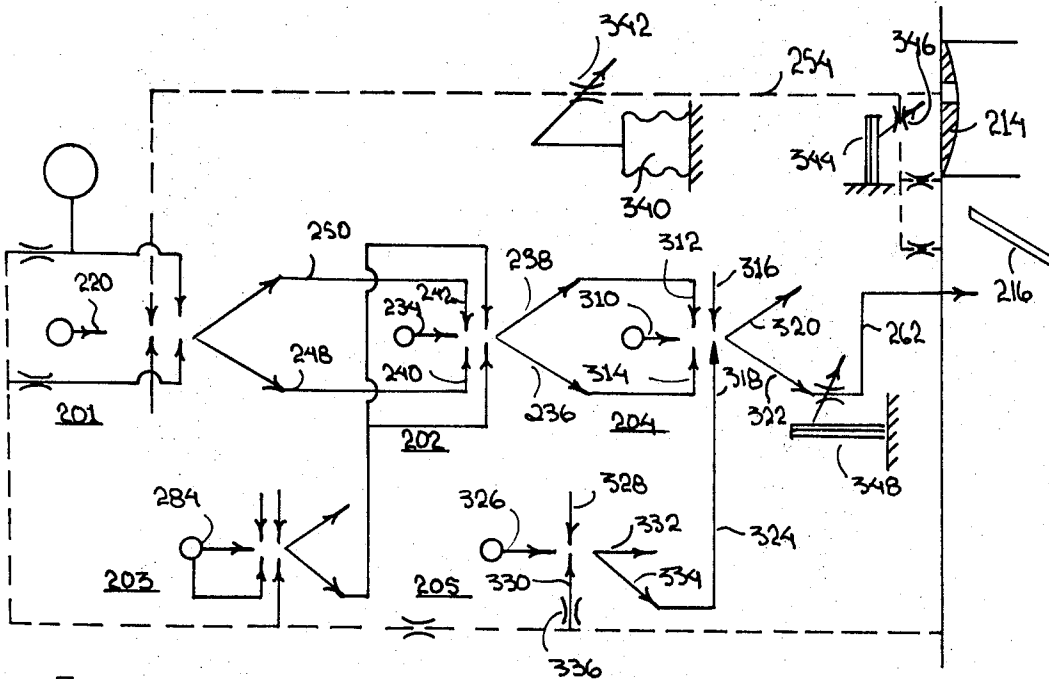
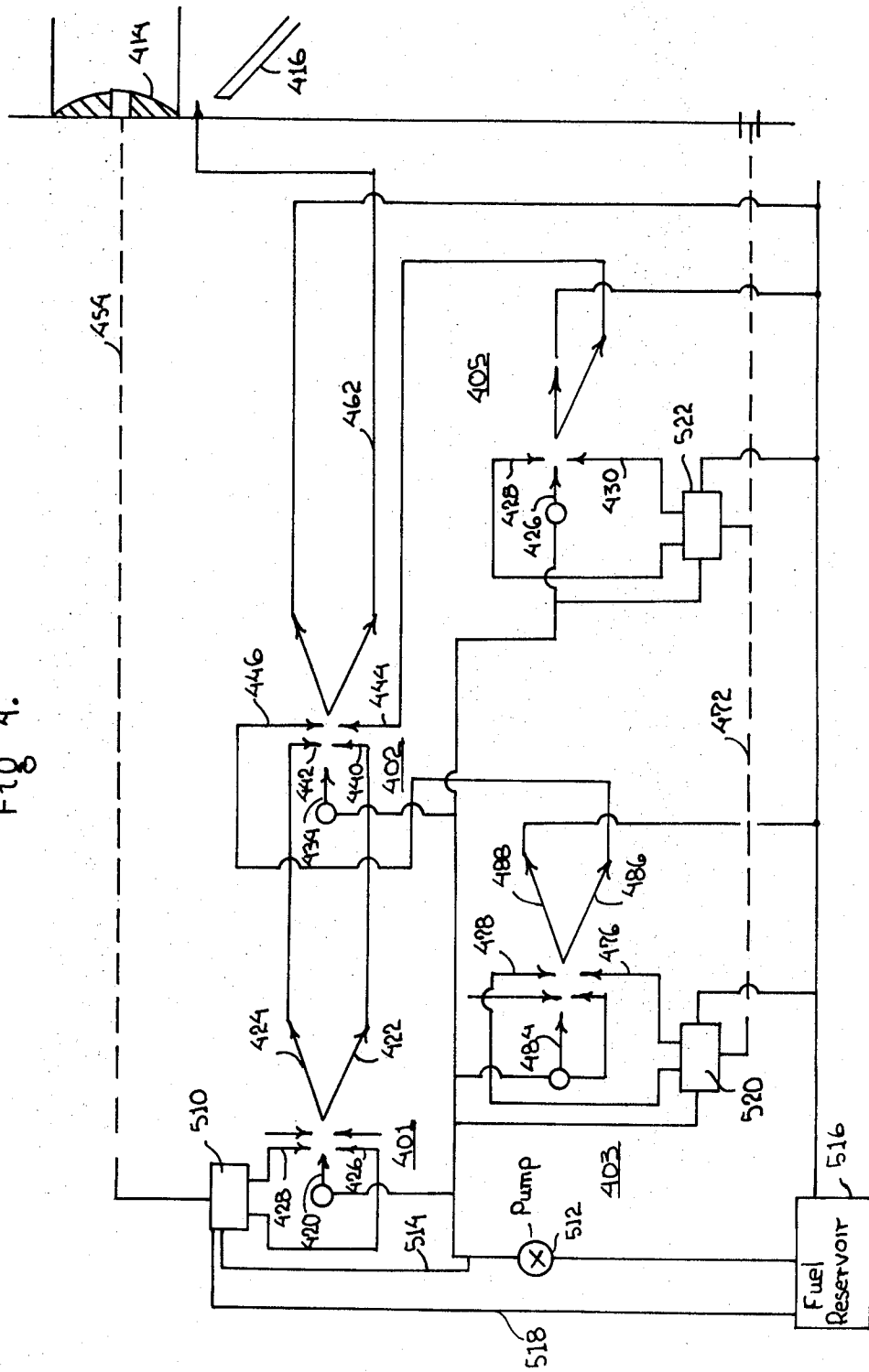


Fig 3.

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Fig 4.



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FUEL SYSTEM

BRIEF SUMMARY OF THE INVENTION

The concept of applying fluidic devices to perform fuel control functions is known and offers the prospect of providing a highly compact, low cost control with performance at least comparable with present day devices such as the well-known carburetor.

However, the task of displacing the highly developed carburetor is not an easy one since special attention needs to be given to fluidic fluid power sources and recirculating connections which impose added cost. It is believed that maximizing the usage of fluidic elements, permitting lower cost integrated circuit manufacturing techniques, will offset the cost increment mentioned, and provide a system more than competitive in both cost and performance. That further such a system can be a closed system to minimize evaporation of raw fuel and can otherwise meet the most stringent low emissions requirements. Accordingly, it is an object of the invention to provide a fluidic control having idle, acceleration, power enrichment devices compatible with a primary fluidic amplifying circuit.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic drawing of a fuel system and an air intake passage wherein the system incorporates fluidic elements in a first embodiment of the invention;

FIG. 2 illustrates one form of air-to-liquid transducer which may be used in conjunction with the present invention;

FIG. 3 is a schematic drawing of a second embodiment of the invention including an additional stage of amplification and deceleration cutoff and temperature and pressure correction means; and

FIG. 4 is a schematic drawing of a third arrangement of the invention utilizing fluidic amplifiers operating entirely with liquid supply and control signals.

DETAILED DESCRIPTION

A schematic representation of a fluidic control circuit in accordance with the principles of the present invention is shown in FIG. 1.

An engine air intake manifold is designated by numeral 10 and includes sequentially in the direction of airflow, an air entrance 12, a venturi 14, a movable throttle valve 16, and downstream passage section 18 supplying air to an engine of the piston type, not shown.

The control circuit consists essentially of three proportional fluidic amplifier generally designated by numerals 1, 2, and 3, as indicated, plus connecting, sensing and delivery passages. Reference is made to U.S. Pat. No. 3,122,165, published Feb. 25, 1964, in the name of B. M. Horton as an illustration of a class of fluidic proportional amplifiers suitable for practicing the present invention.

Primary control of establishing a fuel/air ratio proportional to airflow to the engine is exercised by amplifiers 1 and 2 which are connected in series to provide two stages of amplification.

Amplifier 1 consists of a power supply jet 20 receiving, comparatively speaking, high-pressure fuel from the engine fuel pump which is directed towards the output legs 22 and 24. Control over the relative proportion of fuel received in each output leg is exercised by fluid from two sets of transversely-arranged control jets, each set designated by numerals 26, 28, and 30, 32 respectively.

Amplifier 2 is similarly constructed having a power supply jet 34 receiving high-pressure fuel, output legs 36 and 38 and two sets of transverse control jets 40, 42, and 44, 46.

Output legs 22 and 24 of the amplifier 1 are connected via passages 48, 50 to the control jets 40, 42, respectively of amplifier 2 to provide two stages of amplification.

A control signal pressure differential reflecting airflow to the engine is obtained from the pressure pickup probe 52 in the throat of venturi 14 which is connected by passage 54 to control jet 28 of the first amplifier. The opposed control jet 26

is connected by passages 56 and 58 to static probe 60 measuring atmospheric pressure upstream of the venturi. The differential pressure thus supplied by control jets 26, 28, is a reasonably good index of airflow and has been the primary control parameter in the well-known carburetors. Increasing airflow through intake manifold 10 produces an increased pressure differential across control jets 26, 28, deflecting more fuel into output passage 24 creating a stronger signal at control jet 42 than at jet 40 in the second stage amplifier. Thus, greater quantities of fuel are deflected out of output passage 36 which is connected by passage 62 to a fuel delivery point or nozzle in the intake manifold. The action above described provides increased fuel to maintain the basic desired fuel/air ratio. Fuel from passage 38 is returned to the fuel tank or other suitable reservoir for recirculation.

POWER ENRICHMENT

Means are provided for enriching the fuel/air mixture supplied to the engine through a selective range of low manifold vacuum conditions measured downstream of throttle valve 16, as for example at port 70. Manifold vacuum is transmitted via passage 72 and restriction 74 to control jet 76 of amplifier 3. Amplifier 3 has a supply jet 84 supplied with relatively high-pressure fuel, two sets of control jets 76, 78 and 80, 82, respectively, and a pair of outlet passages 86, 88. Control jet 80 is connected through pressure reducing restriction 90 and passage 92 to the source of high pressure fuel to provide a permanent bias deflecting the main supply jet out passage 88 where it is returned to the fuel tank or reservoir. Control jets 78, 82 may be either vented directly to the atmosphere or connected to atmosphere vent passage 58. The advantage of connecting all atmospheric vents to passage 58 and port 60 would be to provide clean air to installations where an air filter is used upstream of the intake manifold.

At high manifold vacuum in the range commensurate with idle and part throttle conditions, the vacuum in control jet 76 is sufficient to overcome the bias of control jet 80 and shift the main supply jet out outlet passage 86. High-pressure fuel is transmitted through passage 94 to the common junction 96 of branch passages 98 and 100. High-pressure fuel is ejected from control jets 44 and 46 in a balanced and opposed direction and produce the effect of restricting the gain of amplifier 2 in proportion to the intensity of pressure being supplied to the control jets.

As the engine approaches wide open throttle and full load conditions, manifold vacuum will decrease to a point where it is no longer dominant over the bias pressure in control jet 80 and the output begins to shift in a proportional manner from passage 86 to passage 88. As the pressure is reduced at control jets 44, 46 of amplifier 2, amplifier gain is increased and fuel is enriched for power operation. Amplifier 3, thus has saturation limits so that it is operative to produce an output change only over a selected range of input change.

ACCELERATION

Control jets 30 and 32 of amplifier 1 are connected to branch passages 102, 104, respectively, each having a restriction 106, 108 and a common junction 100. Junction point 110 is connected to an extension of passage 72 containing manifold vacuum. Branch passage 104 is connected to a volume 112 which acts as a capacitance. Volume 112, together with the restrictions 101, 108, establishes a differential flow impedance in the two branch passages. When manifold vacuum is at a stable value, control jets 30 and 32 have equal vacuum signals and do not effect the output of amplifier 1. During an acceleration, however, manifold vacuum is a changing quantity and due to the differential impedances, the change is more quickly felt at control jet 30 and is caused to lag at control jet 32. This causes a pressure differential to exist between jets 30 and 32 which is the derivative or rate of change of manifold vacuum which temporarily deflects more fuel into outlet passage 24 of amplifier 1 producing, in turn,

augmented fuel delivery for a temporary acceleration condition. As acceleration is completed, manifold vacuum again becomes stable and the effect of control jets 30 and 32 neutralized.

IDLE ENRICHMENT

At engine idle, the airflow through venturi 14 becomes too low to maintain an adequate control signal. This is a well-known venturi characteristic which, in the established carburetor art, manifests itself by the usual provision of separate main and idle fuel systems in a given carburetor. In my fluidic system, idle enrichment is accomplished by modifying the fuel/air ratio established by the primary system rather than by the provision of a separate system. An idle bleed port 120 is located in the intake manifold downstream of throttle plate 16 where it is exposed to a strong vacuum at idle conditions. The idle bleed port is shown as adjustable to permit selective adjustment for the ideal idle setting. Idle bleed port 120 is connected via passage 122 and restriction 124 to passage 54 normally transmitting the mass airflow signal from the throat of the venturi. A second or so called "off idle port 126", is connected in parallel with idle port 120 and is located immediately upstream of the throttle plate such that opening movement of the throttle plate beyond idle causes the off idle port to pass from the upstream to downstream side of the throttle plate.

At high engine speed and load conditions with throttle plate open or near open, manifold vacuum is low and the flow through venturi 14 high, so that the mass airflow signal from the venturi probe 52 is the predominating control signal. As the engine approaches idle condition, as by closure of the throttle valve 16, the venturi flow becomes less and that signal weakens, whereas manifold vacuum strongly increases by a factor of five to ten times. It will be apparent the pressure transmitted from the idle circuit through restriction 124 will be higher than absolute pressure measured at port 120, and during idle conditions, will be intermediate pressures at ports 52 and 120. This pressure may be set by adjustment of variable bleed 120 to establish desired idle flow. The off idle port not only establishes a higher pressure source to permit the adjustment flexibility just mentioned, but also, provides a more gradual transition between manifold vacuum control to venturi control to meet engine characteristics.

An idle air bleed passage 130 including variable restriction 132 is shown by passing throttle valve 16 which may be considered as closed during idle. Thus, idle airflow may preferably be separately established, however, it will be understood that normal leakage around valve 16 or a partly open position of valve 16 may be used to establish idle airflow.

In the fuel system described, the high-pressure fluid source to the fluidic amplifiers has been taken from the fuel supply as a readily available pressurized fluid source. Some vehicles have air compressors or hydraulic sources which may be used. It is felt, however, that use of fuel both as the controlled quantity and the primary fluid medium offers some simplification of the circuit design.

Amplifiers 1 and 3 connected as illustrated in FIG. 1, utilize two fluid mediums, i.e. liquid fuel and air. While it has been demonstrated that such two medium devices perform in a functionally-credible manner, the possibility of air entrainment in fuel lines and vice versa represents an uncontrolled condition which can have an effect on metering accuracy in certain cases. Air entrainment is minimized in the first instance by utilizing two stages of amplification wherein the second amplifier 02 operates with basically liquid supply and control pressures, although small quantities of air may be present in the control signals. While such measures seem adequate at present, emissions control in future years (beyond 1970) may impose metering accuracy requirements which will require still further consideration of the entrainment problem.

FIG. 2 illustrates a suitable pneumatic to liquid interface transducer device which may be used to convert all air control signals to liquid to enable all amplifiers to operate with one

liquid medium, if desired. For descriptive purposes, the interface device will be described as utilized to convert the airflow signal to amplifier 1 from a pneumatic signal to a push-pull or double liquid signal.

Venturi throat pressure and/or idle circuit pressure is supplied by conduit 54 to one face of diaphragm 150 contained in housing 152, whereas the reverse diaphragm side is exposed to atmospheric pressure which may be obtained simply by providing a central opening 154. Diaphragm 150 is connected by link 156 to an elastic spring tube 158 which provides a known deflection characteristic and a fuel to air seal. Tube 158 is connected to housing 160 and has a flapper valve 162 depending from its upper end into the interior of housing 160. A pair of control nozzles 164, 166 project into housing 160 on opposite sides of the flapper valve 162. High-pressure fuel is supplied from manifold 168 through branch passages 170, 172, containing restrictions 174, 176 respectively to passages 178, 180 which are each connected to one of the control nozzles. Passages 178, 180 may be connected to the control jets 26, 28 of amplifier 1 (FIG. 1) which are represented by load orifices 182, 184. Fuel is returned to the fuel tank or reservoir from housing 160 via passage 186. Variation of pneumatic pressure on either side of diaphragm 150 will deflect flapper valve 162 so that the lower end changes its spacing from the nozzles 164, 166. Since a limited amount of fuel passes through restrictions 174, 176, variation of the spacing of flapper 162 from nozzles 164, 166 will establish the fuel pressure level in conduits 178, 180, thus transducing the pneumatic into a liquid signal suitable for use as an amplifier control signal. It will be understood that other pneumatic to liquid transducers may be used in the present invention.

In addition to the basic system and components described to this point, specific engine applications may require additional functions of deceleration cutoff, altitude compensation, and cold idle enrichment which can be readily added to the basic system with very elemental add-on components.

Referring to FIG. 3, amplifiers 201, 202 and 203 functionally-correspond to amplifiers 1, 2 and 3 of the three element circuit of FIG. 1, and functionally-similar parts of the FIG. 3 embodiment bear numerals in the two hundred series, but having the same tens and ones digits as their corresponding elements in FIG. 1. Two additional fluidic amplifiers 204 and 205 are added to the circuit. Amplifier 204 is a proportional amplifier, and has a supply jet 310 receiving pressurized fuel as a supply fluid and contains opposed sets of control jets 312, 314, and 316, 318. Output passages 320, 322 are provided with 320, the dump passage, and passage 322, the fuel delivery passage, connected through conduit 262 to the fuel delivery point. Control jets 312 and 314 are connected to the output passages 238, 236, respectively, of the second stage amplifier 202. Thus, amplifiers 201, 202 and 204 provide three stages of amplification in series in this embodiment.

It will be noted that this fuel injection point in FIG. 3 is illustrated as below the throttle plate 216, in which location the possibility of "carburetor icing" of the throttle plate is eliminated. Added flexibility in the point of injection is obtained since the venturi signal is used only as a sensing signal and not for the purpose of propelling the fuel into the manifold as with conventional carburetors.

Control jet 316 of amplifier 204 is open to the atmosphere whereas control jet 318 is connected by passage 324 to deceleration cutoff amplifier 205. Amplifier 205 is a monostable amplifier which contains a main fluid supply jet 326 supplied by pressurized fuel, a pair of control jets 328, 330, and output passages 332 and 334.

Supply fluid is normally delivered out output passage 332 which is aligned with supply jet 326, thus defining a monostable amplifier. A restriction 336 is provided in control jet passage 330, restricting communication with manifold vacuum in line 272. Control jet passage 328 is left open to the atmosphere. Restriction 336 is sized to require a predetermined high manifold vacuum to be present in line 272, before sufficient force is exerted at control jet 330 to deflect the

supply jet from its stable position to its unstable position delivering an output to output passage 334. For example, if restriction 336 is sized so that switching to passage 334 occurs only at manifold vacuums approximating 20 inches Hg and above (variable to a degree with engine design), amplifier 205 will provide a deceleration fuel cutoff function. In this connection, manifold vacuums in excess of 20 inches Hg are only present during engine decelerations when throttle plate 216 is in its most closed position and the engine is above idle speed. Switching in output to passage 334, of course, presents a control signal at jet 318 of amplifier 204 deflecting fuel from the delivery passages 322 and 262. As the engine coasts down and approaches idle, manifold vacuum will fall below the fuel cutoff level established and fuel delivery will be resumed.

Altitude idle compensation is provided by evacuated bellows 340 controlling variable restriction 342 in line 254 providing a basic altitude correction on the primary airflow signal from venturi 214.

A bimetal temperature deflecting beam member 344 controls variable restriction 346 in the idle circuit to adjust for variations in idle fuel enrichment required between cold and hot engine starts. This bimetal control could control both fast idle fuel and air by also connecting the bimetal to an air restriction, such as restriction 132 of FIG. 1, eliminating the need for the equivalent of a fast idle cam of present day choked carburetors. Bimetal 344 would be located to sense engine heat. Bimetal element 348 controls variable orifice 350 in fuel delivery line 262 and is responsive to ambient temperature for hot day correction.

Referring to FIG. 4, another embodiment of my invention is illustrated having amplifiers operating entirely with liquid fluid. Amplifiers 401, 402, 403, and 405 functionally-respond to amplifiers 201, 202, 203, and 205 of the FIG. 3 embodiment. Amplifiers 401 and 402 provide first and second stages of amplification for the basic airflow circuit. Amplifier 403 provides power enrichment override control, and amplifier 405 deceleration cutoff override.

The airflow signal from venturi 414 is transmitted by passage 454 to air-to-liquid transducer 510 of the type described and illustrated in FIG. 2 to supply control jet pair 426, 428 with a liquid control signal proportional to airflow. Liquid fuel is supplied to transducer 510 from fuel pump 512 through passage 514, and is returned to fuel reservoir 516 via passage 518. Fuel in output passages 422, 424 of first stage amplifier 401 is supplied as a control signal to control jet pair 440, 442 of second stage amplifier 402. The power enrichment amplifier 403 receives a liquid control signal at control jets 476, 478 from transducer 520 which is proportional to manifold vacuum transmitted from passage 472. The output in line 486 is transmitted as a one point input to control jet 446 of amplifier 402 where it proportionally deflects the output, leaving control jet 444 free to receive a signal from deceleration cutoff amplifier 405. In this embodiment, it is possible to eliminate the equivalent of third stage amplifier 204 of the FIG. 3 embodiment. Such an additional amplifier may, of course, be reintroduced if it is desired to have additional stages of amplification or additional control jets for accepting other control signals. Amplifier 405 also operates with an air-to-liquid transducer 522.

The FIG. 4 embodiment operates in a functionally-similar manner, providing a basic mass airflow proportional fuel control with superimposed power enrichment and deceleration cut off functions. In this arrangement, a hydraulic connection for the fuel recirculation circuit are illustrated and the transducers are utilized at each air-to-liquid interface point. Thus, the possibility of air entrainment in fuel is avoided.

I claim:

1. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:
 - proportional fluidic amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by said venturi means in response to selected changes in manifold vacuum; and said control means including a pair of branch passages having different fluid impedances therein to develop a control signal proportional to the rate of change of manifold vacuum.

2. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:

proportional fluidic amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by said venturi means in response to selected changes in manifold vacuum; and said control means including a fluidic element having saturation limits operative to supply an augmenting fuel control signal within a selected range of values of manifold vacuum.

3. A fuel control system as claimed in claim 2 wherein said proportional fluidic amplifier means includes at least one set of aligned and directionally-opposed control jets interconnected to one another to provide a gain control variable with pressure intensity applied in a balanced and opposed direction at said set of control jets, said interconnected set of control jets connected to said control means so that amplifier gain is varied in response to changes in manifold vacuum.

4. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:

Proportional fluidic amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

Venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by said venturi means in response to selected changes in manifold vacuum; and

said proportional fluidic amplifier means including at least one set of aligned and directionally-opposed control jets interconnected to one another to provide a gain control variable with pressure intensity applied in a balanced and opposed direction at said set of control jets; said interconnected set of control jets connected to said control means so that amplifier gain is varied in response to changes in manifold vacuum.

5. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:

proportional fluidic amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by said venturi means in response to selected changes in manifold vacuum;

said proportional fluidic amplifier means including at least two proportional interconnected fluidic amplifier elements providing two stages of amplification;

said signal transmission means interconnecting said venturi means to one of said two proportional amplifier elements; and

said control means connected to the other of said two proportional amplifier elements.

6. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:

proportional fluid amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by said venturi means in response to selected changes in manifold vacuum;

idle port means in said intake manifold downstream of said throttle valve operative a strong vacuum at idle conditions; and passages means interconnecting said idle port means with said signal transmission means to modify and enrich fuel delivery at idle conditions.

7. A fuel control system for an engine having an air intake manifold and a throttle valve in said manifold comprising:

proportional fluidic amplifier means having at least two control jets operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jets;

venturi means adapted to be located in the intake manifold receiving air delivered to an engine operative to develop a control pressure which varies with variations in airflow through the venturi means;

signal transmission means interconnecting said venturi means to one of said control jets to control fuel delivery in response to variations in airflow;

control means connected to the other of said control jets having an opening communicating with manifold vacuum at a location downstream of the throttle valve to modify the fuel delivery established by the venturi means in response to selected changes in manifold vacuum; and

said control means including a monostable fluidic element operative to develop a fuel reduction controlling signal only about a predetermined high manifold vacuum reflective of engine deceleration.

8. A fuel control system comprising:

proportional fluidic amplifier means having a control jet operative to control fuel delivery to an engine in response to variations in fluid pressure supplied to said control jet;

a saturable fluidic proportional amplifier having a pair of outlet passages and means normally biasing a fluid supply jet to one of said pair of outlet passages;

said other of said pair of outlet passages connected to said control jet to supply a controlling fluid pressure to said proportional amplifier means;

means responsive to a condition of engine demand supplying a control signal to said saturable proportional amplifier to thereby control fuel delivery during selected conditions of engine demand;

said proportional fluidic amplifier means having a set of opposed interconnected control jets providing a gain control variable with fluid pressure supplied to said control jet; and

said other of said outlet passages of said saturable proportional amplifier connected to said set of control jets to control amplifier gain in response to selected conditions of engine demand.

9. A fuel control system as claimed in claim 8 wherein the means responsive to engine demand manifold vacuum.

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